Subsonic Wake Characterization of the Orion Capsule using PIV in the Ames UPWT 11-foot Wind Tunnel

James T. Heineck[1], James C. Ross[1], Gloria K. Yamauchi[2]

[1] NASA Ames Research Center, Experimental Aero-physics Branch

[2] NASA Ames Research Center, Aeromechanics Office

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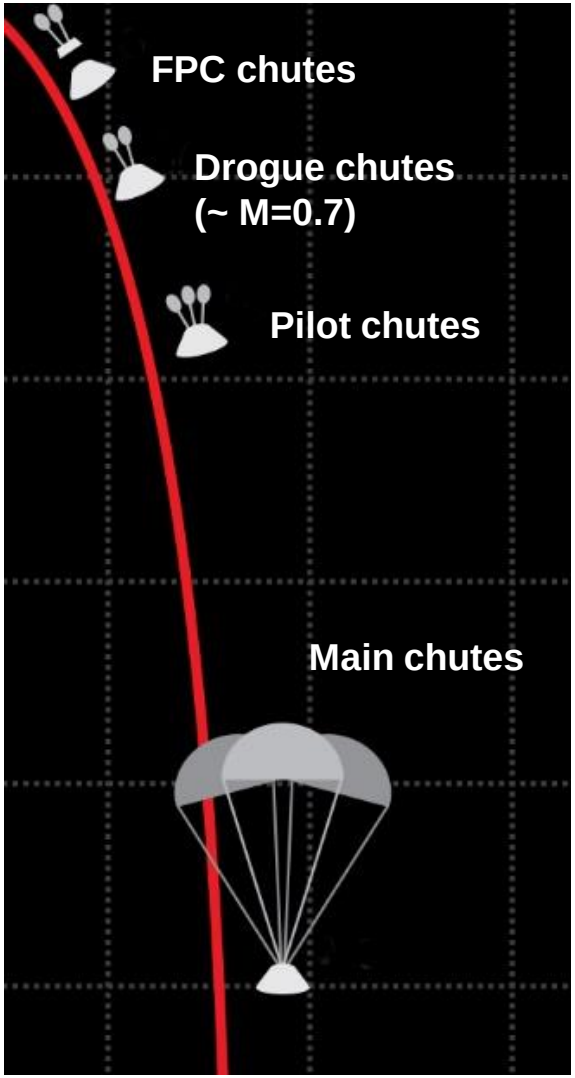
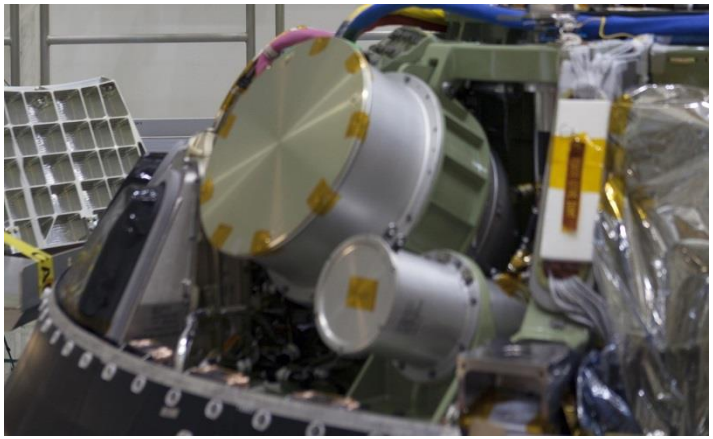
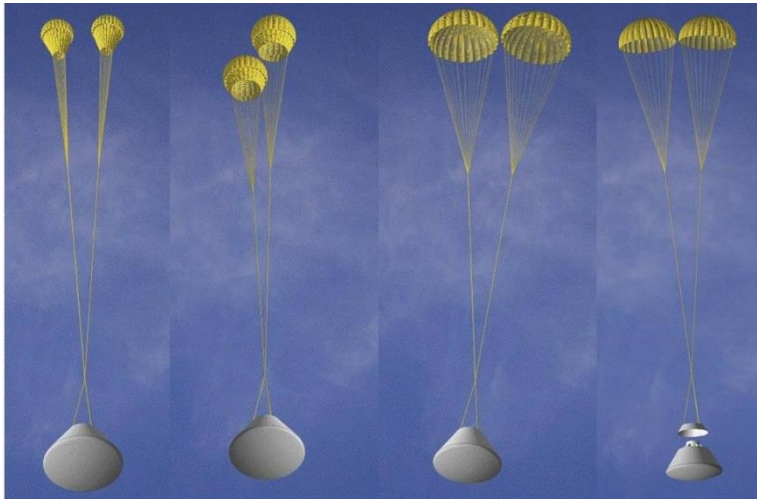
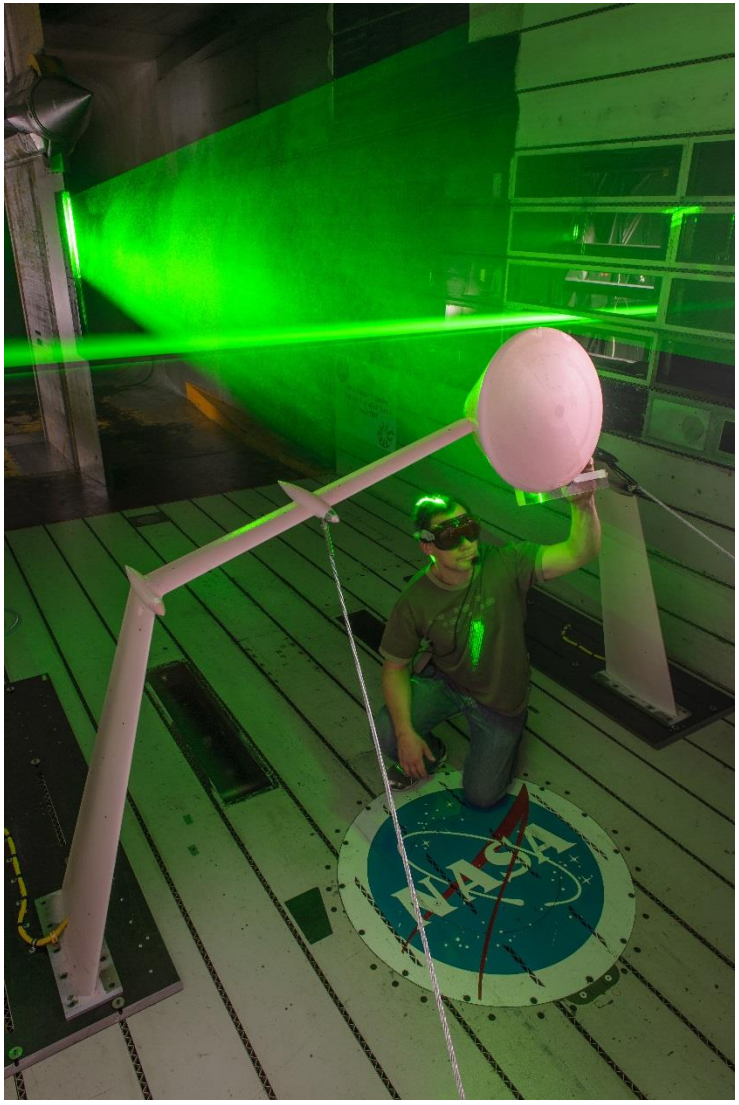
Background: Orion Crew Module EDL









Why this test?

Aero database of the Orion capsule did not match data from the Pad Abort 1 test

- **CFD- difficulty with modeling the wake in subsonic regime**
- **Inadequate wind-tunnel data**

NASA required PIV for drogue chute deployment risk assessment/retirement

Future chute design focusing on lighter materials

NASA Engineering and Safety Center role

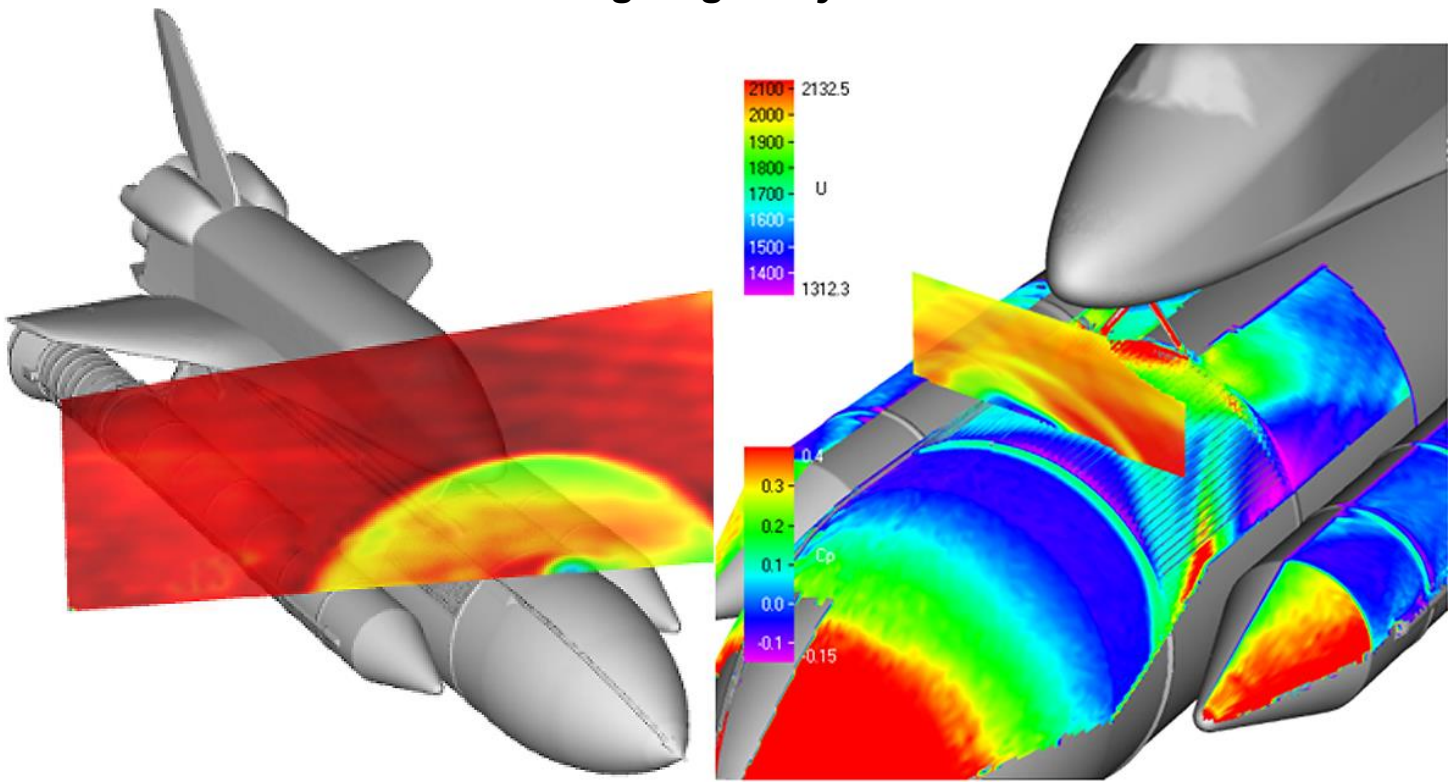
This is an example of how PIV has evolved in the two decades – from lab-table to major wind tunnel tests for risk reduction analysis

Precedence: Shuttle Return to Flight, 2004

After the Columbia Accident in 2002, NASA re-assessed the safety environment for the Shuttle and its Operations

New predictive codes were developed that required PIV for validation

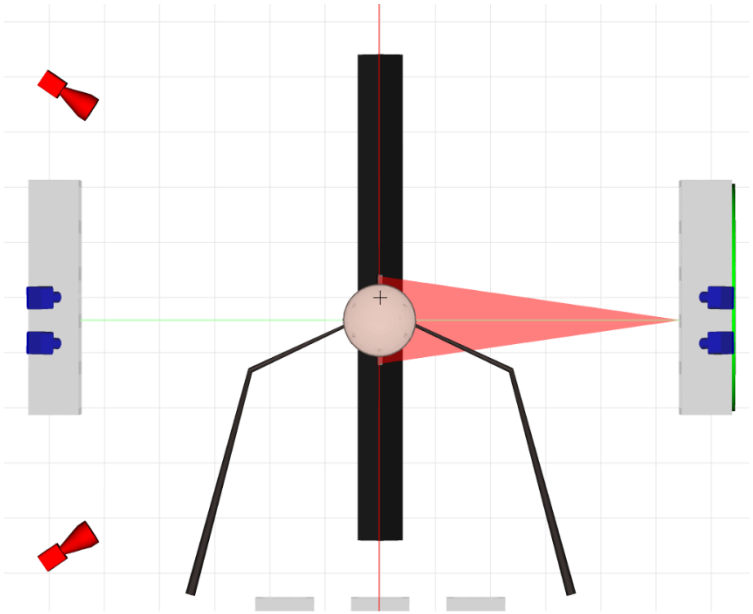
"We aren't going to fly without this data."



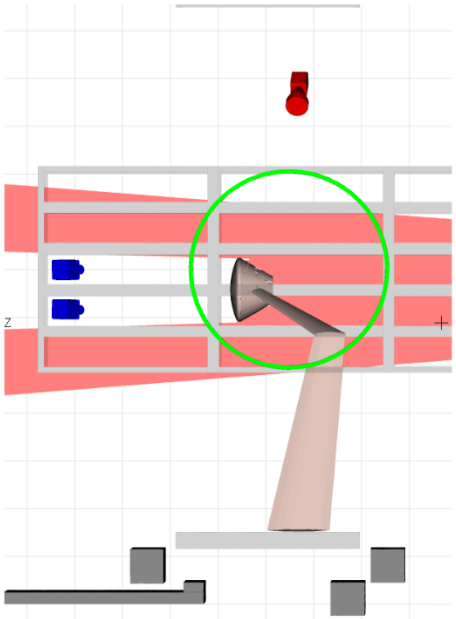
Assessing the environment for parachute deployment

16 inch (40.6 cm) Simplified Orion Crew Module Model with strut designed specifically for the PIV measurements – move to two locations to obtain X/D~ 6

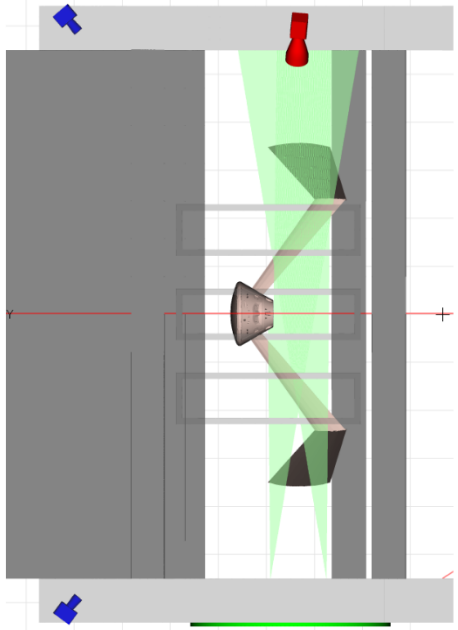
Test included Thermal Imaging for transition detection, PSP, Skin-friction measurements, and high-speed shadowgraphy along with PIV to help CFD code development



Front view



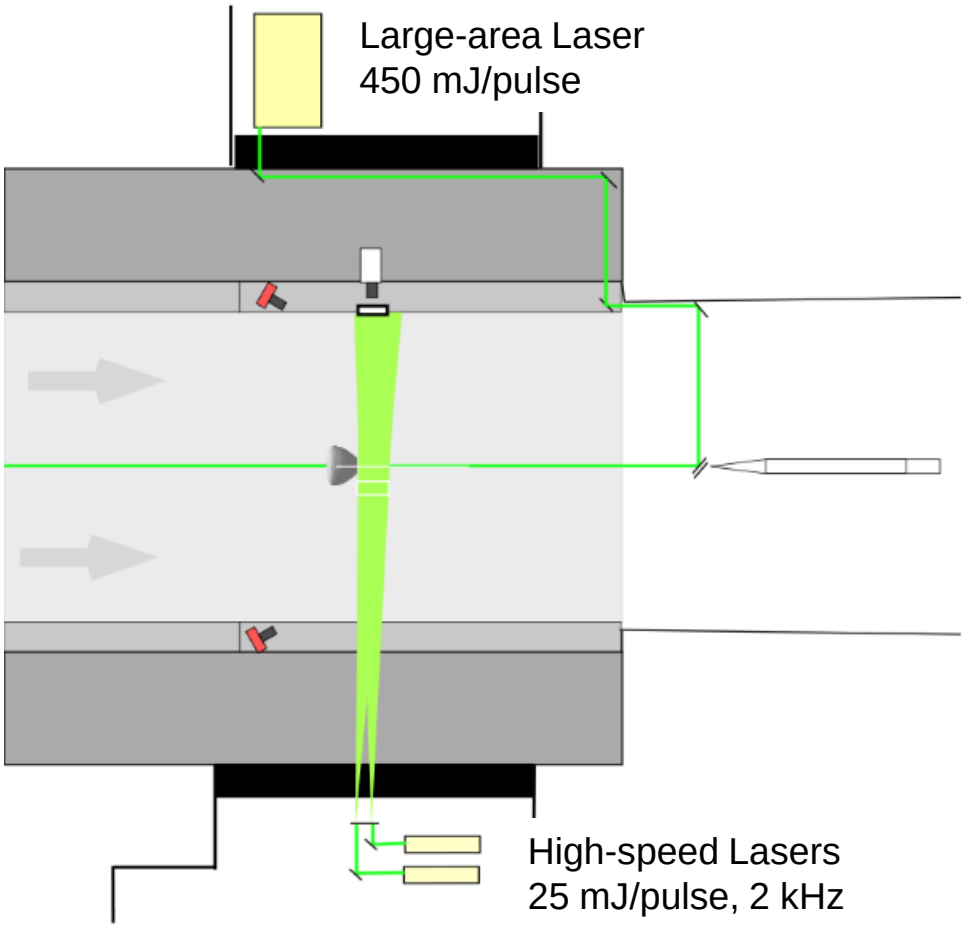
Side view



Top view

PIV data acquisition

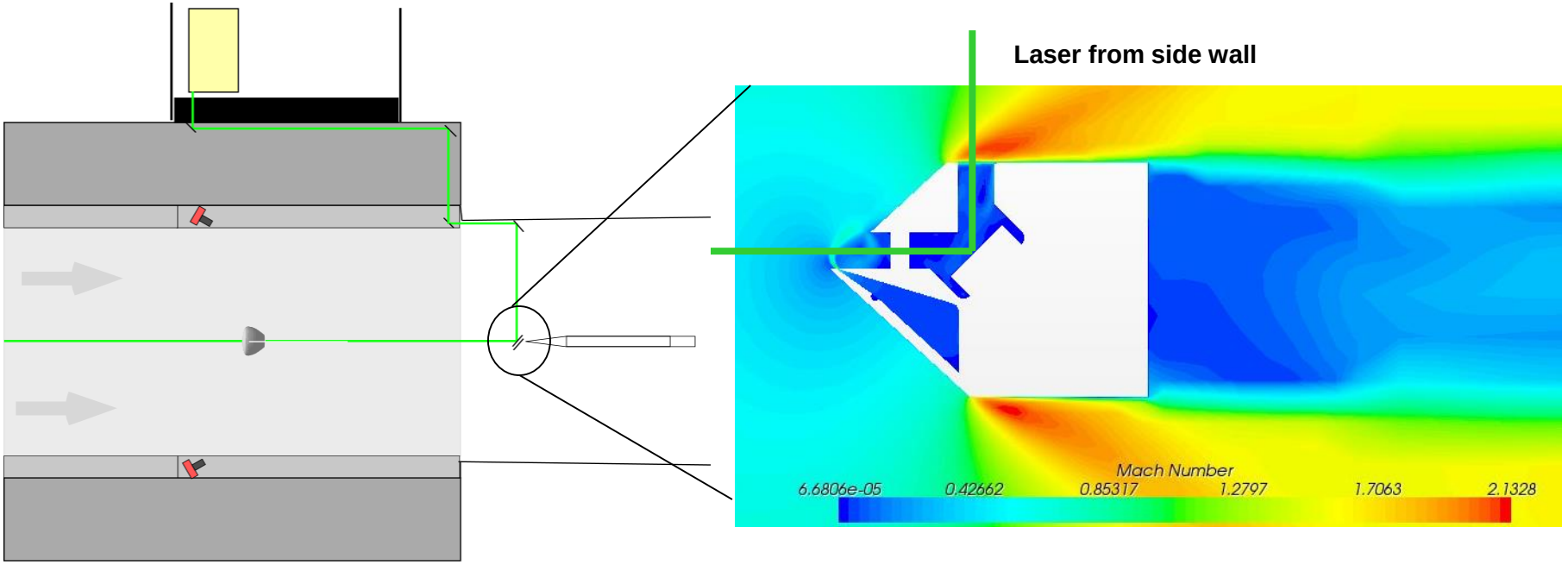
- **Two separate 3C PIV systems: Large Area in Vertical Stream-wise plane and high-speed for the shear layer measurement**
- **Large Area system: 11 mpix cameras covering 4 feet (1.2 m) x 2.5 feet (0.64 m) at 2 Hz**
- **2000 samples needed for each condition for turbulence statistics**
- **Model moved upstream to mosaic x/D 3.5-6**



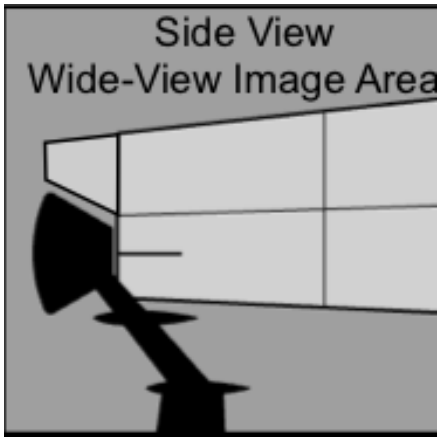
Designing the laser path for wide-area PIV

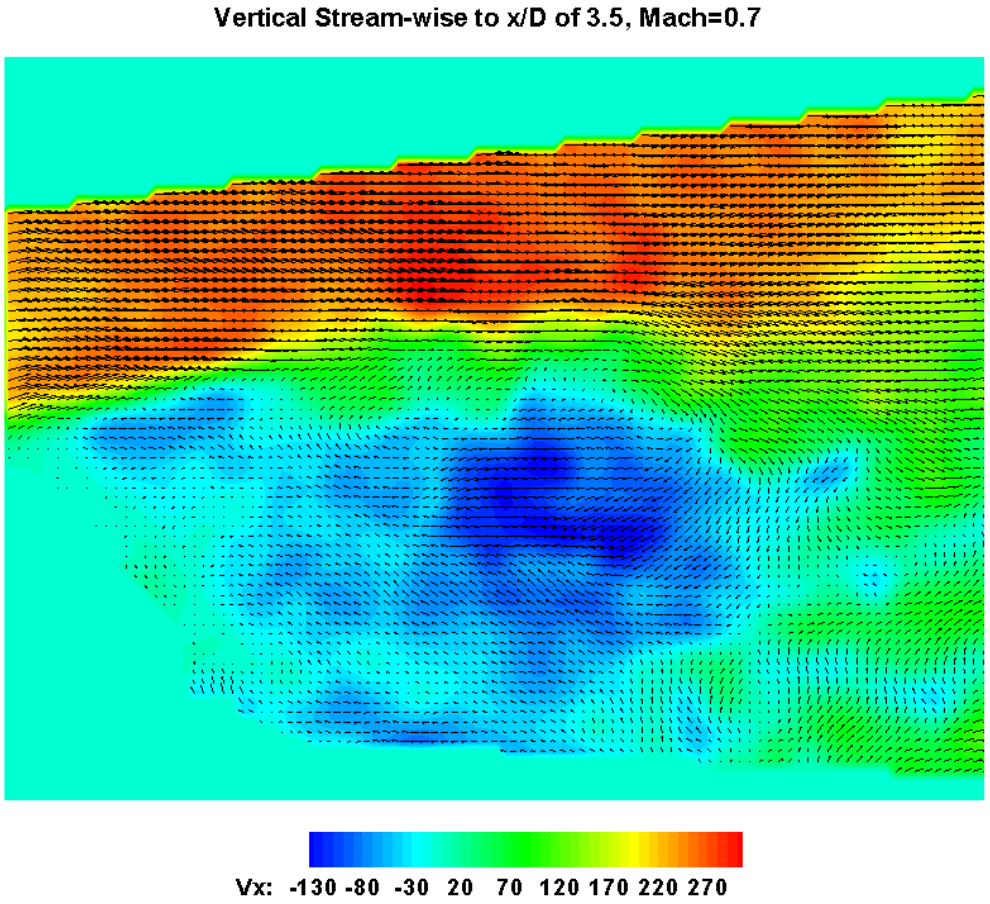
Passing the laser through the outer shell, through the plenum, into a box on the diffuser wall to a 45degree mirror on the strut to go upstream on the tunnel centerline.

The final mirror, mounted to the strut, required and air-knife to keep seeding from building on the window surface. CFD used for design



Wide Area PIV Data





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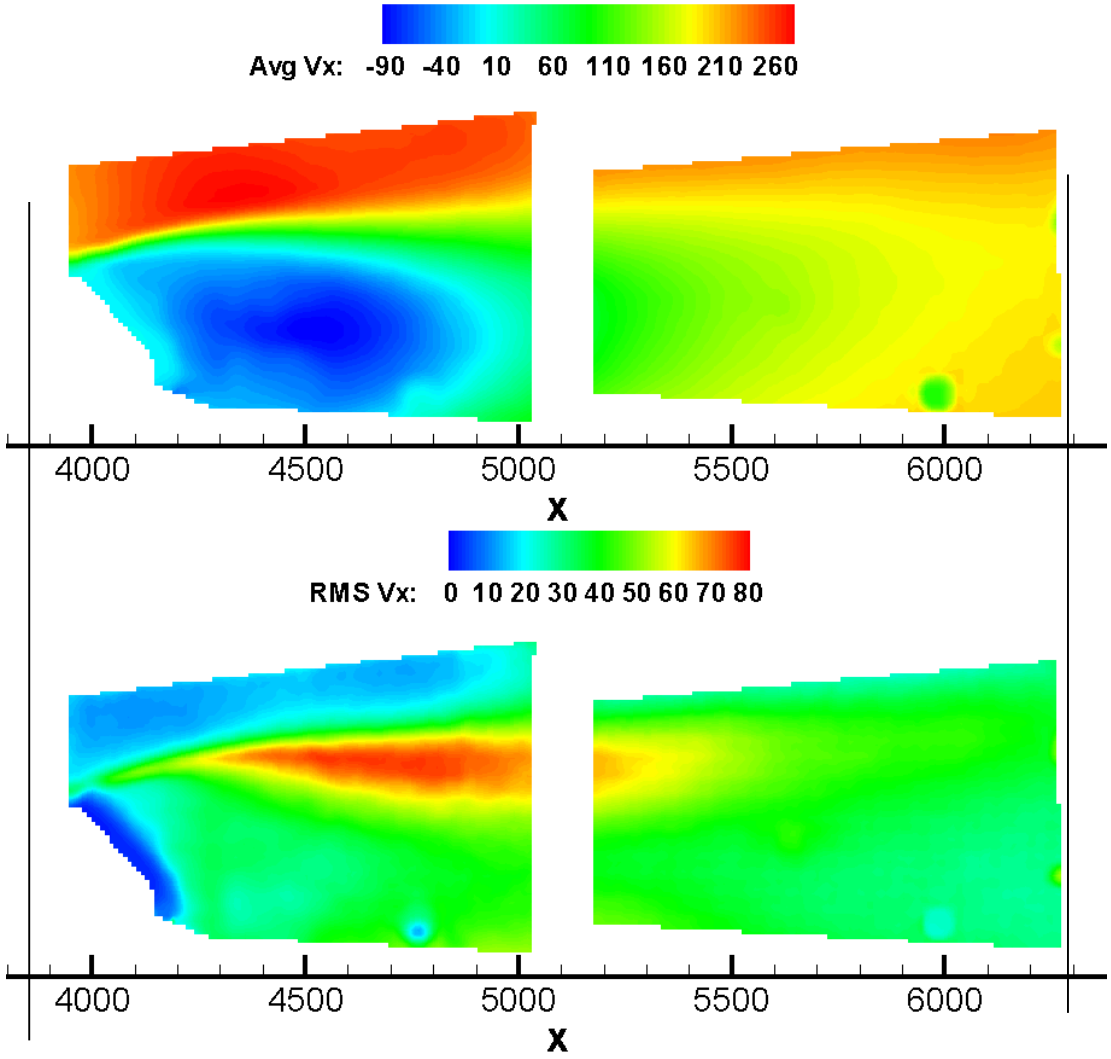


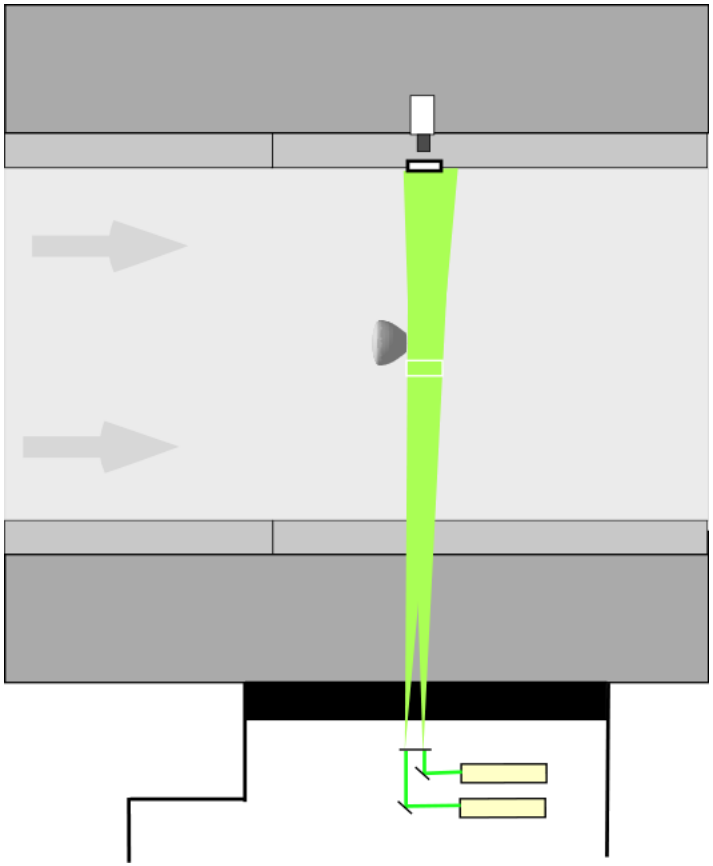
Model Origin Stream-wise Plane

Model 6D Stream-wise Plane

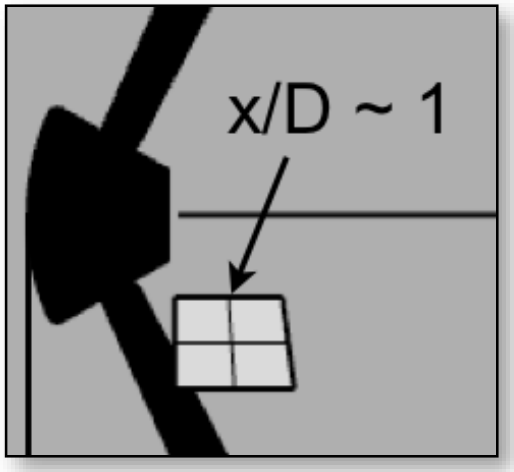
High-speed system: 4 Mpix cameras, 2 kHz PIV

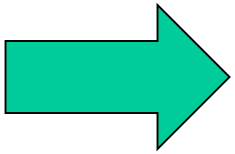
New cameras gave us high resolution and high frequency

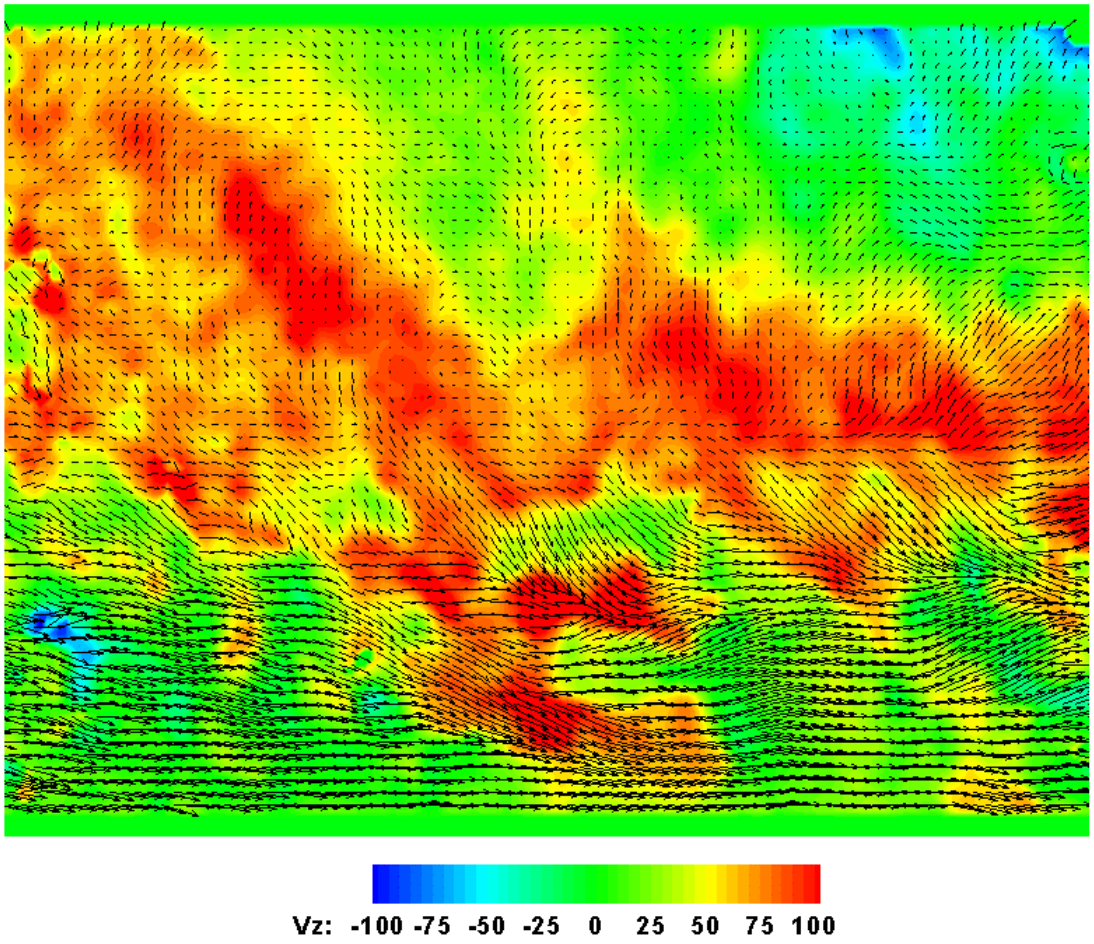
Two Nd:YLF PIV lasers (four beams combined to one sheet)



High Speed PIV of Shear Layer







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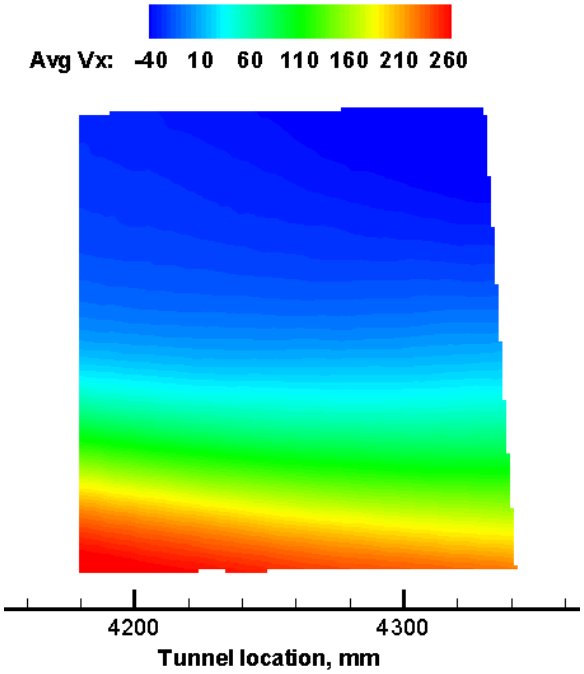
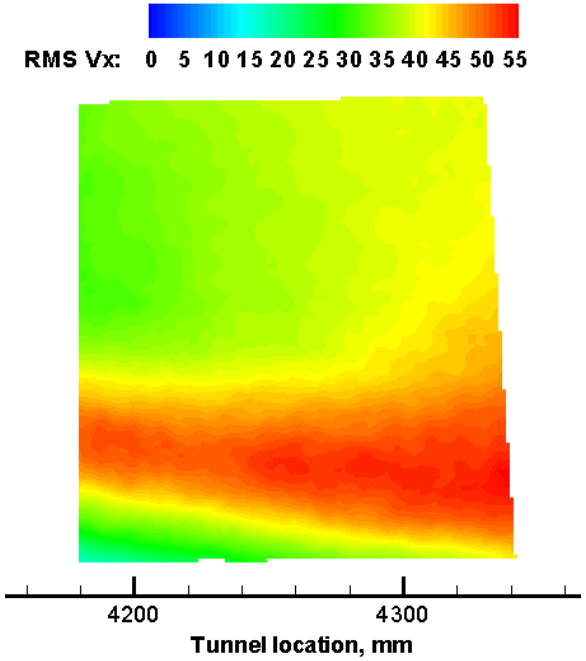
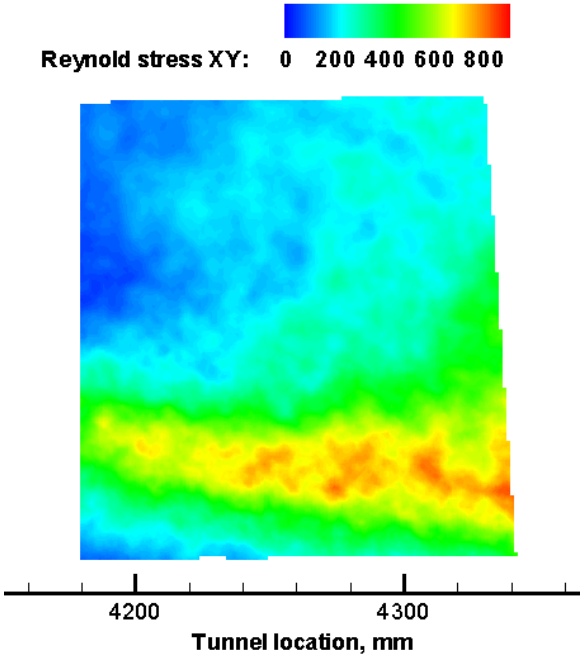






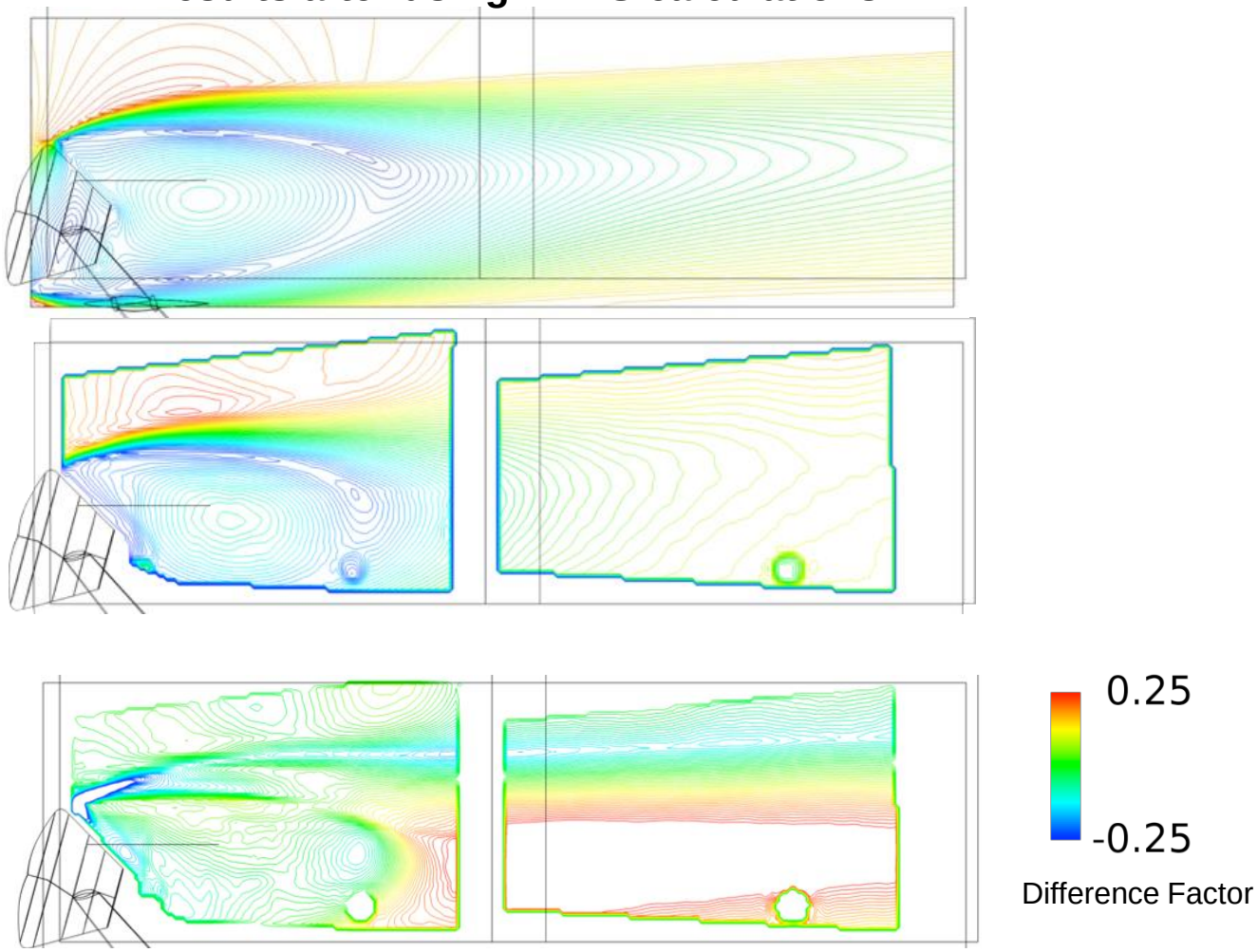
CFD Comparisons

Results after using RANS calculations

RANS

PIV

RANS - PIV



From: “Simulation Of Atmospheric-Entry Capsules in The Subsonic Regime”, Scott Murmon, Robert Childs, Joseph Garcia, AIAA SciTech 2015

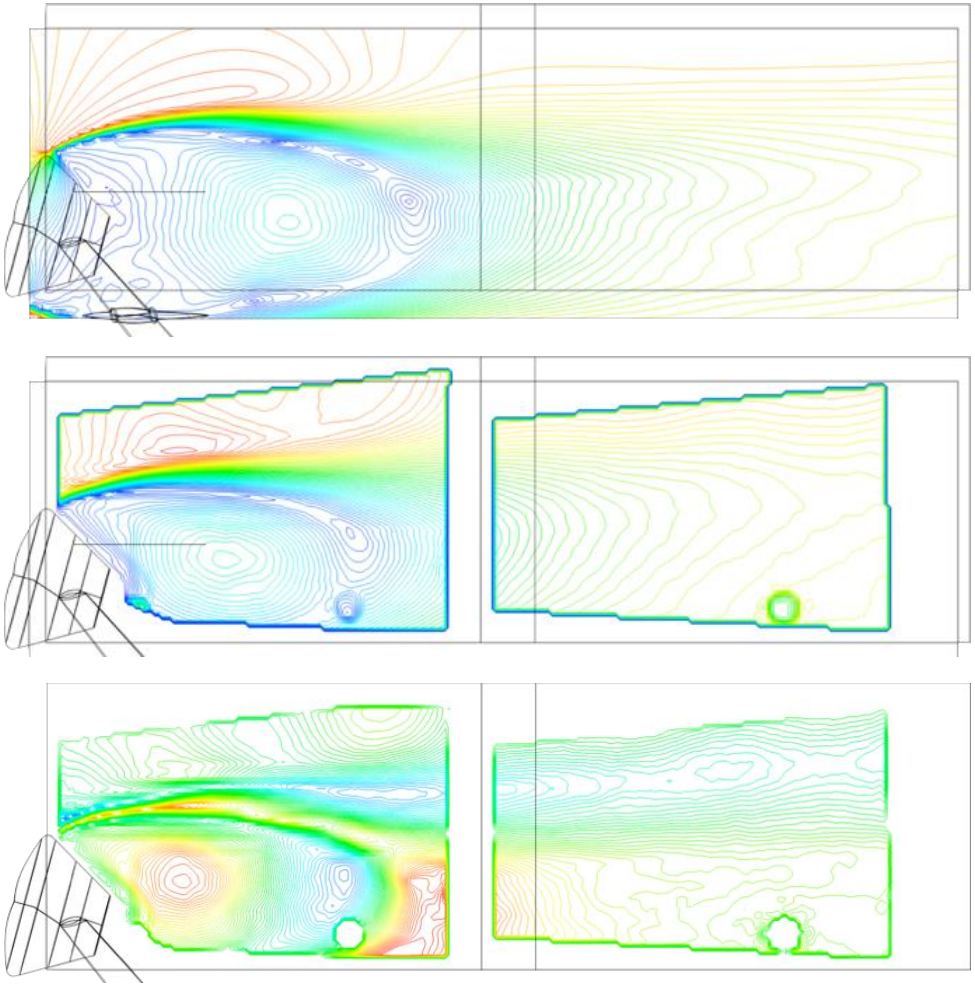
CFD Comparisons

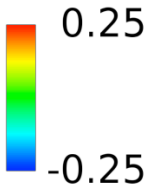
Results after using time-accurate DES

DES

PIV

DES - PIV





Difference Factor

From: “Simulation Of Atmospheric-Entry Capsules in The Subsonic Regime”, Scott Murmon, Robert Childs, Joseph Garcia, AIAA SciTech 2015

Take-aways

PIV has become an industrial strength measurement for difficult-to-model flows

It has become trusted to provide benchmark datasets for CFD and aerodynamic device designers

Advances in hardware (computers and cameras) will further improve the technique

NASA has come to trust its use for safety-critical risk reduction analysis

Acknowledgements

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